# 5.9 GHz Dedicated Short Range Communication Vehicle-based Road and Weather Condition Application

# Messaging Requirements

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REVISION HISTORY

| Version | Description |
|---|---|
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| | |

## 1. Introduction

Significant effort has been expended in the Federal Highway Administration's (FHWA) Road Weather Management Program and in various federal and state connected vehicle programs to identify opportunities to acquire data from vehicles acting as mobile sensor platforms. It is also well-recognized that weather has a significant impact on the year-round operations of the nation's roadway system. This 5.9 GHz Dedicated Short Range Communication (DSRC) Vehicle-based Road and Weather Condition Application project is the synergistic result of those converging opportunities.

Accurate, timely and route-specific weather information allows traffic and maintenance managers to better operate and maintain roads under adverse conditions. The research system developed by this project will collect weather observation data from mobile sensors on transportation agency vehicles; transmit the data by way of DSRC roadside equipment (RSE) to one or more collection systems; and ultimately make the data available to other information systems such as the New York State DOT INFORM system and the U.S. DOT's Weather Data Environment. In this way, the additional weather information from mobile platforms will eventually enable traffic managers and maintenance personnel to implement operational strategies that optimize the performance of the transportation system by mitigating the effects of weather on the roadways.

This document will define the mobile data messaging requirements against which the research application will be designed and implemented. The desired data elements will first be identified, and then be compared against the data elements that are available. The comparison exposes the gaps between the intent and the implementation and illustrates that not all desired data elements may be captured in practice.

Following the identification of data elements, applicable connected vehicle communication and messaging standards are reviewed. These in turn, drive the message formats and the subsequently documented messaging requirements.

### 1.1 References

*IEEE Std 802.11p™, IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments.*

*IEEE P1609.0™/D0.9, April 2010, IEEE Draft Standard for Wireless Access in Vehicular Environments (WAVE)—Architecture.*

*IEEE P1609.1™/D1.3, May 2010, IEEE Draft Standard for Wireless Access in Vehicular Environments (WAVE)—Remote Management Services*

*IEEE Std P1609.2™ Draft 9.3 Draft Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages.* IEEE, IEEE SA Standards Board; September 2011.

*IEEE Std 1609.3™, IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Networking Services.*

*IEEE Std 1609.4™, IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-Channel Operation. Vehicle Information Exchange Needs for Mobility Applications Version 3.0 –FHWA-JPO-12-021*; RITA Intelligent Transportation Systems Joint Program Office, April 15, 2013.

*SAE J1939 Companion Spreadsheet – CS1939-042012.* SAE International, January 11, 2013.

*SAE J1979 E/E Diagnostic Test Modes.* SAE International, Vehicle E/E System Diagnostic Standards Committee, February 23, 2012.

*SAE J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary.* SAE International, DSRC Technical Committee; November 19, 2009.

*ASD Spec v. 3.0; USDOT Aftermarket Safety Device Specification v. 3.0.*

*"5.9GHz DSRC Roadside Equipment" Device Specification v.3.0,* USDOT, March1, 2012.

*Clarus System Design – System Design Description*; Mixon/Hill, Inc., September 2009.

### 1.2 Definitions and Acronyms

| Term | Definition |
|---|---|
| ASD | After-market Safety Device. A specific implementation of on-board DSRC equipment connected directly to a vehicle data bus, with the additional purpose of providing safety-related feedback to the vehicle operator. |
| CAN | Controller Area Network. An electrical specification and signaling protocol developed by Bosch to facilitate simple data communication between connected equipment control units. |
| *Clarus* Initiative | A Federal Highway program supporting the open sharing of weather data with the goal of enabling transportation agency decision support systems that improve safety and reduce costs. |
| *Clarus* System Instance | Existing *Clarus* System software functionality and data captured at a specified and agreed upon date and time. The instance is expected to evolve into the WxDE and is not intended to replace the current operational *Clarus* System. |

| Term | Definition |
|---|---|
| DSRC | Dedicated Short Range Communication. A low-latency, line-of-sight wireless data transmission standard designed for interactions between vehicles and infrastructure in a dynamic transportation environment. |
| Interim Environment | Temporary environment in which the *Clarus* instance is hosted and maintained, until the WxDE becomes available. |
| FTP | File Transfer Protocol |
| HTTP | Hyper-Text Transfer Protocol |
| IEEE | Institute of Electrical and Electronics Engineers. |
| OBE | On-board equipment. DSRC equipment connected directly to a vehicle data bus. |
| PID | Parameter identifier. A unique code used in a controller area network to request specific equipment operational and state data. |
| PGN | Parameter Group Number. A unique identifier used as a network address in the SAE J1939 data standard to group similar data parameters. |
| PSID | Provider service identifier. |
| RSE | Road-side equipment. DSRC equipment deployed near a roadway or intersection. |
| SAE | Society of Automotive Engineers. |
| SPN | Suspect Parameter Number. A lower-level identifier within a PGN that describes what a particular data value represents, its update frequency, and its unit of measure. |
| STOL | Saxton Transportation Operations Laboratory |
| U.S. DOT | United States Department of Transportation |
| WDE or WxDE | Weather Data Environment |

## 2. Analysis

The analysis, data element details, and resulting message requirements described in this document may appear to be brief. This is due mainly to the extensive groundwork performed under many previous U.S. DOT connected vehicle research projects. Ultimately, the messaging requirements are simply directives to implement the applicable connected vehicle standards. However, this document serves to provide some context for the referenced standards and describe how they apply to the Weather Condition Application project goals. This document may be updated when new information—perhaps such as aftermarket equipment parameters that may provide

data elements of interest—is uncovered during the execution of the project aftermarket that was not initially known to the project.

### 2.1 Standards

The Open Systems Interconnection (OSI) model is a conceptual model that characterizes communications system functions by grouping similar functions into one of seven logical layers: physical, data link, network, transport, session, presentation, and application.

In the context of connected vehicles, the physical layer is formed by the radio and radio control that conforms to IEEE 802.11p and is inherent in the OBE and RSE. The IEEE 1609.x series of Wireless Access in Vehicular Environments (WAVE) standards cross-cuts the OSI model somewhat: 1609.0 contains an overall architecture of the WAVE system; 1609.1 defines remote management services; 1609.2 defines security services for messages; 1609.3 defines integration of common networking services such as Internet Protocol; and 1609.4 defines multi-channel radio operation. SAE J2735 occupies the presentation layer in the OSI model since it provides data encapsulated as messages.

The network, transport, and session layers handle information routing, guaranteed delivery, and persistent connection functions. The messages being used for this project do not require any communication functions in those layers. The Weather Data Environment and New York State INFORM systems occupy the application layer, but are also outside the scope of this message requirements document.

This project will deploy equipment conforming to the latest versions of the OBE (ASD v. 3.0) and RSE specifications (v. 3.0) and transmitted messages will need to conform to IEEE 1609.2 to support the inclusion of security certificates as they become available. The SAE J2735 standard applies to the message formatting necessary to convey weather-related J1939 observations.

Ideally, the SAE J2735 probe vehicle data and “A la Carte” messages would be used to present both standard weather-related parameters and any additional weather-related J1939 parameters not covered directly by the probe vehicle data message. However, at the time of this writing, RSE only support receiving the Basic Safety Message (BSM). Consequently, BSM part 2 will be used instead.

### 2.2 Data Elements

Two SAE standards, J1939 and J1979, were consulted to determine what weather-related elements are available from vehicle data buses. Another SAE standard, J2735, was consulted to determine what weather-related elements are desired by connected vehicle applications. J1979 is reviewed for the case of non-heavy vehicles being available for

this research project. J1939 is specifically for heavy vehicles such as snowplows. J2735 is useful independent of the vehicle data bus.

Three weather-related data gaps will be identified: J1939 and J1979 data elements of interest that are not directly represented by a J2735 message , data elements in BSM part 2 that are not directly available from the common J1939 or J1979 data elements, and data elements of interest that are provided by third-party equipment but defined by the manufacturer.

### 2.2.1 J1939 and J1979 Data Elements Not Represented in J2735

Two weather-related data elements are apparent in the common set of parameter identifiers (PIDs) for J1979: identifier 51 for barometric pressure and identifier 70 for ambient air temperature. The remaining PIDs primarily relate to emission controls as that is the focus of the diagnostic test mode standard. Other weather-related parameters may be available dependent upon the vehicle manufacturer, but there is no guarantee that they can be discovered or are available on the CAN bus.

J1939 parameter group numbers (PGN) and their associated suspect parameter numbers (SPN) for weather-related data are excerpted from the J1939 companion spreadsheet and included in Appendix A for reference. Most of the J1939 PGNs record engine performance, emissions compliance, input controls, and diagnostics. The weather-related J1939 parameter groups can be summarized as fifth-wheel, blade, lights, ambient, and future. The future data elements—water depth, wind, environmental, salinity, and meteorological station—are not yet fully defined and appear to be directed more toward fixed weather observation platforms than vehicles. It is presumed that mobile friction is derived from a fifth-wheel measuring device, but all installed fifth-wheel devices may not be specifically for that purpose.

The vehicle status data frame captures all of the available weather data elements from J1979 and most of what is available from J1939, except for road surface temperature and blade status.

### 2.2.2 J2735 Data Elements Not Represented by J1939 and J1979

The J2735 standard defines data elements and data frames which are frequently used and reused within other data frames and messages. The J2735 basic safety message (BSM) Part 2 consists of several J2735 data frames including the Vehicle Status data frame, which in turn contains the desired data elements (and is also referenced by the Probe Vehicle Data Message). The Vehicle Status data frame is therefore examined for the weather-related data elements as it applies to all messages that incorporate it. BSM Part 2 with expanded data frames is included in Appendix B, copied from the Vehicle Information Exchange Needs document. Pertinent weather data elements from the Vehicle Status data frame are amplified in bold.

There are fourteen weather-related data elements in the vehicle status data frame, repeated here from Appendix B for convenience:

- Exterior lights
- Wiper status front
- Wiper rate (front)
- Wiper status rear
- Wiper rate (rear)
- Sun data
- Rain data
- Air temperature
- Air pressure
- Is raining
- Rain rate
- Precipitation situation
- Solar radiation
- Mobile Friction

There is a J1939-specific data frame (DF_J1939-Data Items) referenced within the J2735 vehicle status data frame that focuses on heavy vehicle components such as tire pressure and weight per axle, but it does not include any additional weather elements.

The vehicle status data frame includes solar and rain data that are not directly available from either J1939 or J1979 by default, but may be available from other aftermarket equipment.

### 2.2.3 Third-Party Data Elements

The third-party equipment data gap is most easily understood by examining the currently participating integrated mobile observation (IMO) states: Nevada, Michigan, and Minnesota. Nevada has a few vehicles that report air temperature, relative humidity, atmospheric pressure, and road temperature; but not all vehicles are equipped with every type of sensor. Michigan is similar to Nevada in that they have a few vehicles reporting identical parameters with the addition of dew point temperature. Minnesota, in contrast, captures the same data as Nevada and Michigan with more vehicles and additionally captures material type, rate, granularity, and concentration parameters from Dickey John road treatment equipment. The Minnesota snowplow truck deployment is likely similar to the equipment in New York identified for this project and is used for the gap reference here.

Aftermarket equipment for heavy vehicles has its own manufacturer-defined program group numbers provided via its own J1939 data bus. Weather sensors deployed to non-heavy vehicles may also have their own PIDs and data buses. Data from the added

equipment could fill in the missing solar and rain data gaps as well as provide extra weather-related data not listed in this document. The vehicles proposed for this project will be inspected and inventoried to determine what weather-related data can be captured on a case-by-case basis.

### 2.3 Requirements

Messaging requirements for this project are based on and constrained by the standards and previously successful connected vehicle research projects. The requirements appear obvious and straightforward, but this is due to the focused and well-defined scope of this research project.

1. Messages requiring digital signatures shall conform to the ToBeSigned message format defined by IEEE 1609.2.
2. Messages shall be able to represent all weather-related data collected from a heavy vehicle J1939 data bus.
3. Messages shall be able to represent all weather-related data collected from a vehicle J1979 data bus.
4. Messages shall be able to represent all weather-related data collected from a third-party equipment data bus.
5. Messages shall contain all available weather-related data elements defined by SAE J2735 DF_VehicleStatus in the MSG_BasicSafetyMessage.
6. Messages shall contain weather-related data elements not defined by SAE J2735 DF_VehicleStatus as SAE J2735 MSG_BasicSafetyMessage free-form local content.

## Appendix A – J1939 Weather-Related Parameters

Excerpted from J1939 Companion Spreadsheet

| PGN | SPN | Definition |
|---|---|---|
| 61458 | 3317 | Fifth Wheel Roll Warning Indicator |
| | 3308 | Fifth Wheel Vertical Force |
| | 3309 | Fifth Wheel Drawbar Force |
| | 3310 | Fifth Wheel Roll Moment |
| 61460 | 3366 | Relative Blade Height and Blade Rotation |
| | 3367 | Relative Blade Height Figure of Merit |
| | 3332 | Blade Rotation Angle Figure of Merit |
| | 3365 | Relative Blade Height |
| | 3331 | Blade Rotation Angle |
| 64942 | 3307 | Fifth Wheel Error Status |
| | 3312 | Fifth Wheel Lock Ready to Couple Indicator |
| | 3313 | Fifth Wheel Lock Couple Status Indicator |
| | 3311 | Fifth Wheel Slider Position |
| | 3316 | Fifth Wheel Slider Lock Indicator |
| 64972 | 2873 | Work Light Switch |
| | 2872 | Main Light Switch |
| | 2876 | Turn Signal Switch |
| | 2875 | Hazard Light Switch |
| | 2874 | High-Low Beam Switch |
| | 2878 | Operators Desired Back-light |
| | 2877 | Operators Desired – Delayed Lamp Off Time |
| 64973 | 2864 | Front Non-operator Wiper Switch |
| | 2863 | Front Operator Wiper Switch |
| | 2865 | Rear Wiper Switch |
| | 2869 | Front Operator Wiper Delay Control |
| | 2870 | Front Non-operator Wiper Delay Control |
| | 2871 | Rear Wiper Delay Control |
| | 2867 | Front Non-operator Washer Switch |
| | 2866 | Front Operator Washer Switch |
| | 2868 | Rear Washer Function |
| 65088 | 2404 | Running Light |
| | 2352 | Alternate Beam Head Light Data |
| | 2350 | Low Beam Head Light Data |
| | 2348 | High Beam Head Light Data |

| PGN | SPN | Definition |
|---|---|---|
| | 2388 | Tractor Front Fog Lights |
| | 2386 | Rotating Beacon Light |
| | 2390 | Rear Fog Lights |
| 65089 | 2403 | Running Light |
| | 2351 | Alternate Beam Head Light Data |
| | 2349 | Low Beam Head Light Data |
| | 2347 | High Beam Head Light Data |
| | 2387 | Tractor Front Fog Lights |
| | 2385 | Rotating Beacon Light |
| | 2389 | Rear Fog Lights |
| 65269 | 108 | Barometric Pressure |
| | 171 | Ambient Air Temperature |
| | 79 | Road Surface Temperature |
| 128267 | | Water Depth |
| 130306 | | Wind Data |
| 130310 | | Environmental Parameters |
| 130321 | | Salinity Station Data |
| 130323 | | Meteorological Station Data |

**Appendix B – The Basic Safety Message (Parts 1 and 2)**

The Basic Safety Message (BSM) is one of a set of messages defined in the SAE Standard J2735, *Dedicated Short Range Communications (DSRC) Message Set Dictionary.* Each message in the standard, including the BSM, is made up of a set of *data frames,* which in turn are made up either of other data frames or *data elements*. Data elements are atomic, and are not further subdivided. In a few cases, the text, formal name, and ASN.1 definition found in J2735 provides conflicting information as to whether or not an item is a data frame or data element. For purposes of this analysis, it doesn't really matter.

The BSM consists of two parts: Part 1 is sent in every BSM message and Part 2 consists of a large set of optional elements. Not all elements are available from all vehicles, and which elements are sent, if available, will be based on event criteria that are not specified in J2735.

The major data frames and data elements are listed here. Each item in the list is identified as either a data frame (DF) or data element (DE). If the data frame is not decomposed in this appendix, additional information on its content can be found in SAE J2735. Administrative components such as message ID number and time stamps are not listed in order to keep the list concise and emphasize the informational content that may be of value to mobility applications.

**NOTE: Data elements in bold are weather-related**

**Part 1 (mandatory)**

- Position (local 3D) (DF)
    - Latitude (DE)
    - Longitude (DE)
    - Elevation (DE)
    - Positional accuracy (DE)
- Motion (DF)
    - Transmission and speed (DF)
        - Transmission state (DE)
        - Speed (DE)
    - Heading (DE)
    - Steering wheel angle (DE)
    - Acceleration set (DF)
        - Longitudinal acceleration (DE)
        - Lateral acceleration (DE)
        - Vertical acceleration (DE)

    - Yaw rate (DE)

- Brake system status (DF)
    - Brake applied status (DE)
    - Brake status not available (DE)
    - Traction control state (DE)
    - Antilock brake status (DE)
    - Stability control status (DE)
    - Brake boost applied (DE)
    - Auxiliary brake status (DE)
- Vehicle size (DF)
    - Vehicle width (DE)
    - Vehicle length (DE)

**Part 2 (all elements optional, sent according to criteria to be established)**

- Vehicle safety extension (DF)
    - Event flags (DE) – A data element consisting of single bit event flags:
        - Hazard lights
        - Intersection stop line violation
        - ABS activated
        - Traction control loss
        - Stability control activated
        - Hazardous materials
        - Emergency response
        - Hard braking
        - Lights changed
        - Wipers changed
        - Flat tire
        - Disabled vehicle
        - Air bag deployment
    - Path history (DF)
        - Full position vector (DF)
            - Date and time stamp (DE)
            - Longitude (DE)
            - Latitude (DE)

        - Elevation (DE)
        - Heading (DE)
        - Transmission and speed (DF) – same as in Part 1
        - Positional accuracy (DE)
        - Time confidence (DE)
        - Position confidence set (DF)
            - Position confidence (DE)
            - Elevation confidence (DE)
        - Speed and heading and throttle confidence (DF)
            - Speed confidence (DE)
            - Heading confidence (DE)
            - Throttle confidence (DE)
    - GPS status (DE)
    - Count (DE) – number of "crumbs" in the history
    - Crumb data – set of one of 10 possible path history point set types, consisting of various combinations of:
        - Latitudinal offset from current position (DE)
        - Longitudinal offset from current position (DE)
        - Elevation offset from current position (DE)
        - Time offset from the current time (DE)
        - Accuracy (DF) – See J2735 standard for more information
        - Heading (DE) – NOT an offset, but absolute heading
        - Transmission and speed (DF) – same as in Part 1, NOT an offset
- Path Prediction (DF)
    - Radius of curve (DE)
    - Confidence (DE)
- RTCM Package (DF) – RTCM (Radio Technical Commission for Maritime Services) is a standardized format for GPS messages, including differential correction messages. J2735 states "The RTCMPackage data frame is used to convey a select sub-set of the RTCM messages (message types 1001 TO 1032) which deal with differential corrections between users. Encapsulates messages are those defined in RTCM Standard 10403.1 for Differential GNSS (Global Navigation Satellite Systems)Services -Version 3 adopted on October 27, 2006 and its successors.
    - Full position vector (DF) – see full contents above under Path history
    - RTCM header (DF)

        - GPS status
        - Antenna offset
    - GPS data – see SAE J2735 and RTCM standards for more information

- Vehicle status (DF)
    - **Exterior lights (DE)**
    - Light bar in use (DE)
    - **Wipers (DF)**
        - **Wiper status front (DE)**
        - **Wiper rate (front) (DE)**
        - **Wiper status rear (DE)**
        - **Wiper rate (rear) (DE)**
    - Brake system status (DF) – same as in Part 1
    - Braking pressure (DE)
    - **Roadway friction (DE)**
    - **Sun sensor (DE)**
    - **Rain sensor (DE)**
    - **Ambient air temperature (DE)**
    - **Ambient pressure (DE)**
    - Steering, sequence of:
        - Steering wheel angle (DE)
        - Steering wheel angle confidence (DE)
        - Steering wheel angle rate of change (DE)
        - Driving wheel angle (DE)
    - Acceleration set (DF) – same as in Part 1
    - Vertical acceleration threshold (DE)
    - Yaw rate confidence (DE)
    - Acceleration confidence (DE)
    - Confidence set (DF)
        - Acceleration confidence (DE)
        - Speed confidence (speed, heading, and throttle confidences (DF)
        - Time confidence (DE)
        - Position confidence set (DF)
        - Steering wheel angle confidence (DE)
        - Throttle confidence (DE)

- Object data, sequence of:
  - Obstacle distance (DE)
  - Obstacle direction (DE)
  - Time obstacle detected (DE)
- Full position vector (DF) – see contents under path history
- Throttle position (DE)
- Speed and heading and throttle confidence (DF) – same as above under "Full position vector"
- Speed confidence (DE) – same as above under "Speed and heading and throttle confidence"
- Vehicle data (referred to as a "complex type" in J2735, rather than an element or frame)
  - Vehicle height (DE)
  - Bumper heights (DF)
    - Bumper height front (DE)
    - Bumper height rear (DE)
  - Vehicle mass (DE)
  - Trailer weight (DE)
  - Vehicle type (DE)
- Vehicle identity (DF)
  - Descriptive name (DE) – typically only used for debugging
  - VIN string (DE)
  - Owner code (DE)
  - Temporary ID (DE)
  - Vehicle type (DE)
  - Vehicle class (drawn from ITIS code standard)
- J1939 data (DF)
  - Tire conditions (DF) – see J2735 standard for list of data elements
  - Vehicle weight by axle (DF) – see J2735 standard for list of data elements
  - Trailer weight (DE)
  - Cargo weight (DE)
  - Steering axle temperature (DE)
  - Drive axle location (DE)
  - Drive axle lift air pressure (DE)
  - Drive axle temperature (DE)
  - Dive axle lube pressure (DE)

    - Steering axle lube pressure (DE)
- Weather report, defined as a sequence of the following:
    - **Is raining (DE) – defined in NTCIP standard**
    - **Rain rate (DE) – defined in NTCIP standard**
    - **Precipitation situation (DE) – defined in NTCIP standard**
    - **Solar radiation (DE) – defined in NTCIP standard**
    - **Mobile friction (DE) – defined in NTCIP standard**
- GPS status (DE)